Wave Hydro Dynamics

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Module No. # 03

Wave Deformation

Lecture No. # 03

Wave Deformation and Problems

I hope, now, it is a bit clear about the different types of breaking. So, we have seen this in detail. Having done that, we will just examine, what kind of breakers you could see, under different conditions. For example, off Bay of Bengal, maybe south east coast of India, a kind of breakers you would see, maybe completely different from the type of breakers you would see somewhere near, off Bombay. So, this depends, as I have earlier explained, basically, on three parameters I would say; that is, the beach slope, and then, wave height, and the wave period, or wave length.

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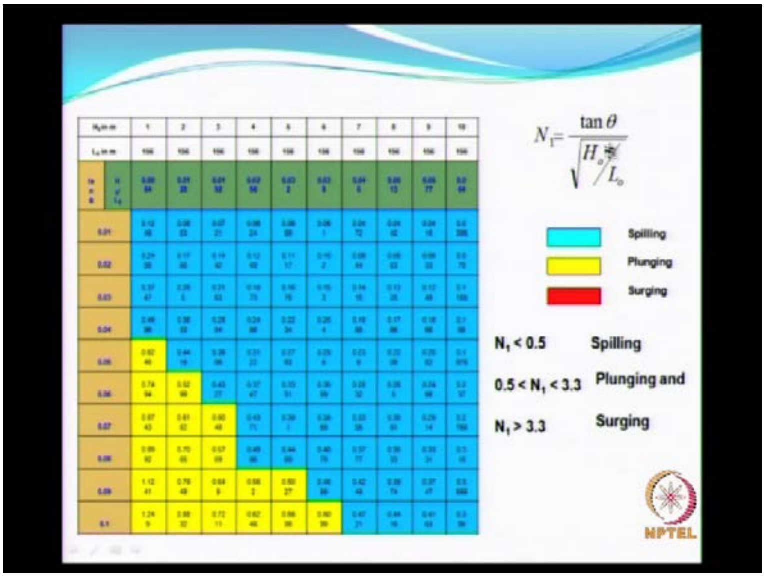

So, the parameter which we had defined earlier is N 1, and N 1 is the ratio of the beach slope and the square root of the wave steepness. So, if you look at this table, what we have done here, here is, we have assumed the deep water wave height as 1 to 10 meters, in intervals of 1 meter; and we have assumed the beach slope here, tan beta, in orange color, as you can see here, from 0.01 to 0.1, insteps of 0.1, 0.01; and then, here the green color, the values given here, is the variation that we have, the values that we have adopted for the deep water wave steepness. So, from this, we are trying to obtain the value of N, as you can see in this. So, you see this blue color spread all over, gives, that the waves are going to be, the breaking of waves would be mostly the spilling type; and, try to recollect the definition of spilling type of breakers. So, you see that, there is a wide, wide range of a wave heights and beach slopes, for which the breaking will be spilling.

So, in general, you can say spilling is most frequently occurring, compared to the other and even plunging, to some extent. So, the plunging breakers, if you see, that is marked in yellow, and this, this is more or less the transition between the spilling and plunging type of breakers. So, for a given site, if you have the wave characteristics, you can very easily examine, what kind of breakers you can anticipate at that particular site. So, you are, here, we have varied deep water wave height, are from 1 to 10 meters, but you can also have deep water wave heights less than 1 meter. So, let us examine, what is the, how the variation would look like, for wave heights less than, I mean, the wave steepness less than 0.1 meter.

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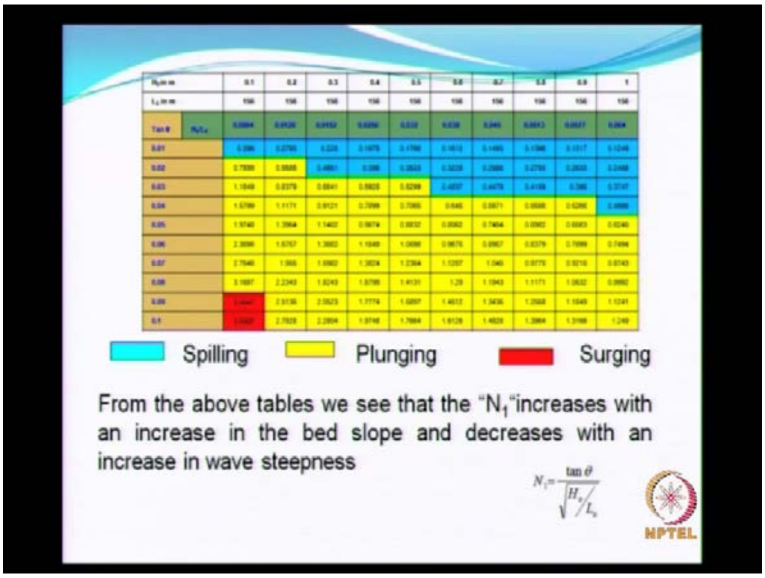

So, for example, here, in the next, in this slide, you see that, we have varied the wave, deep water wave height from 0.1 meters, 0.1 meter to 1 meter, in intervals of 0.1 meter;

and then, you look at the variation of your N value, that categorizes the different types of breaking of waves. Now, you see from this table that, we do have a few points, the conditions under which you can have the surging type of breakers. Surging type of breakers, you should, I am sure you will be in a position to recollect surging type of breakers will occur over steep slopes; very seldom, you would not see them, because normally, the tendency is, we normally go to beaches, where the beach slope is quite flat.

So, you, for example, if you go to Goa, where the beach is quite flat, and you can walk quite a long distance, inside the ocean; and, you will be experiencing kind of spilling type of breakers; and off south east cost of India, for example, Chennai, where you have the major harbor, etcetera, in that vicinity, you will be able to see plunging type of breakers occurring more frequently. So, here, for certain conditions as we have shown here, 0.01 and 0.1 for the beach slope, and very low wave steep, wave height, you see that, you can have your surging type of breakers.

What does the result indicate? The results indicate, from the above table, you can see that, the parameter N 1 that categorizes the types of breakers, increases with an increase in the beach slope, or the sea bed slope, and decreases with an increase in wave steepness. So, this certainly matches with what we have earlier seen that, for flat beaches, the type of breakers you will experience is the spilling type of breakers, and for steep slope, you would have surging type of breakers, and in between, you should have plunging type of breakers. So, this table helps us to understand more clearly, these two tables. So, I suggest you have a critical look at this table, try to understand what could be the wave characteristics. Suppose, if you, if you are, if you are located along the wave, beach, where the beach slope is of certain order of magnitude, which is indicated, try to look at the table, and try to go and examine yourself, whether, what kind of breakers you have.

Now, apart from the three widely classified breakers, there is yet another breaker, which is not that popular, and that is called as collapsing type of breakers. All these breakers, actually, they have been examined through laboratory investigation; the characteristics of these kind of breakers are, have been verified, or have been understood, or studied, only through critical laboratory investigation, a detailed one.

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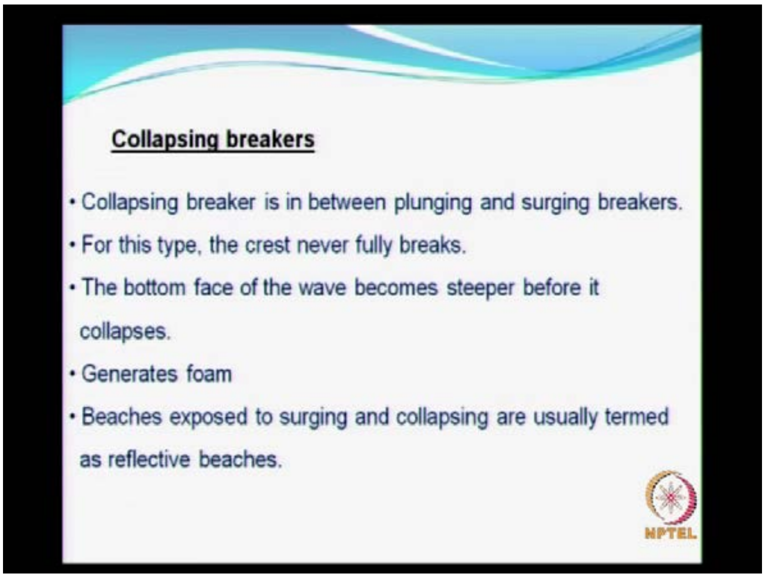

So, they have examined; while doing, so, they have also found out another type of breakers and this collapsing breaker is found to be in between plunging and surging beakers. For this type, the crest never fully breaks. So, the crest will be more or less looking stable; the bottom face of the wave becomes steeper; that is, the bottom portion of the wave becomes steeper and that is before it really collapses; and when it collapses, it generates lot of foam. So, now, surging and collapsing, as we have seen, are mostly due to steep waves, propagating over steep slopes. So, in such case, we can term, or we can call such kind of beaches, where you have this kind of, two kinds of breakers, namely the surging and collapsing, as reflecting beaches. So, I hope that, you have been exposed now, on the details of the wave deformation and also, on wave breaking, the conditions of wave breaking, etcetera and also, now, categorization of your different wave breakers.

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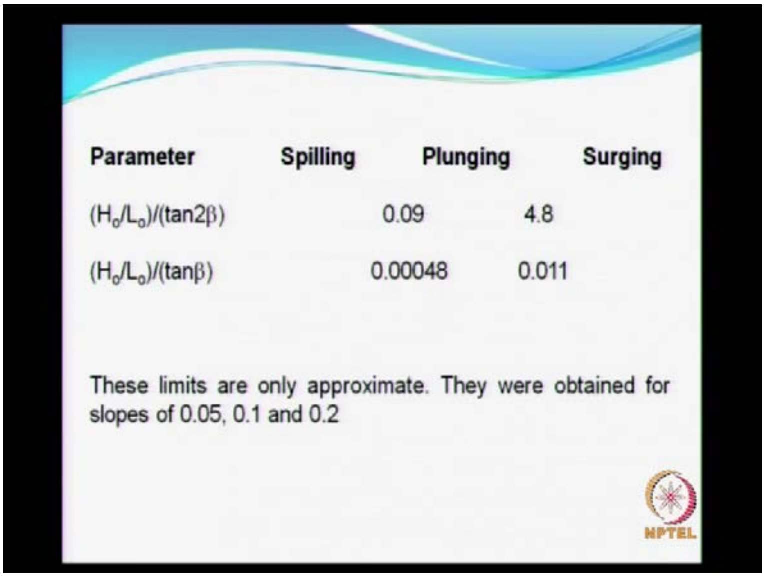

Another kind of classification that has been used widely in literature, apart from the parameter N 1 and N 2, are shown here in this slide. So, we have the parameter here in terms of the deep water wave steepness, and tan beta, tan 2 beta and tan beta; and, the classification is given here, as spilling, plunging and surging; and, their range are shown here; 0.09 for this parameter, and in this case, it should be 0.00048; and, these are all obtained from, based on only experimental investigation. So, naturally, it cannot be holding, it will not hold good, for all kinds of beaches, etcetera; for the slopes, which have been adopted, that is 0.05, 0.1 and 0.2; for few other slopes also, you do have some information, but this should be good enough, as a broad guideline. So, that shows the, that explains the complete description of the spilling, plunging and surging type of breakers.

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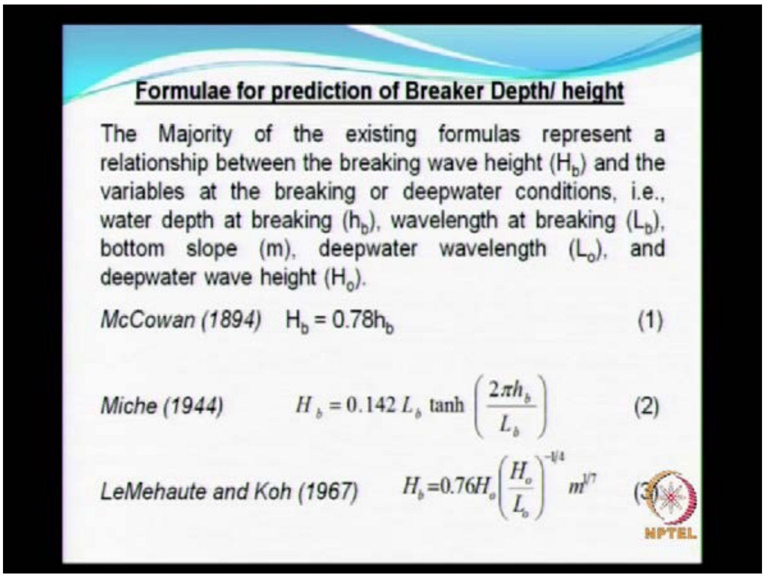

We had earlier looked at the different criteria for the waves to break, and we also saw that, the waves can break not only in shallow waters, but also in deep waters. Waves break in shallow waters because, we see, every time we go to the shallow waters, we see the waves breaking. And, there are certain conditions, or criteria for a wave to break, which I had earlier explained, as the depth limited criteria, which will take place in the shallower waters, or the steepness limited criteria, in the case of deep waters. There are several formulas available in literature, apart from the criteria, which we have seen. For example, McCowan, he has, he is, his relationship is widely used. What is a breaking wave height if you ask, it can be easily said that, it is equal to approximately 0.78 times the water depth. This 0.78 is a kind of an empirical coefficient and some people use it as 0.8.

Then, Miche, he has…So, if you look at McCowan's criteria, you get the breaker wave height as a function of just the breaker depth, and nothing else. For example, if you are, if you are knowing a certain location, this is the location where the wave is breaking, I am talking about the shallow waters, from that depth, you can easily find out what could be the wave height at that point, which will be governed by this relationship.

Miche's criteria, as early as 1944, he has given a relationship between wave height, water depth and of course, breaking wavelength. So, this is another criteria which people use. The third one is LeMehaute and Koh in 67, they obtained an expression, in terms of deep water steepness, deep water wave height and beach slope. So, which formula you want to use? Apart from this, you have several other formulas. It depends on the kind of problem you are working on. So, if you want to have just a firsthand information, like for approximation, you can use the first one, without any problem; but if you want to account for the effect of beach slope, and in case, you have the deep water wave characteristics, like your deep, deep water wave height and the wave steepness, wave, deep water wave height and the wave period, then probably, you, you can use the third one, because this takes care of your beach slope, that is m into, m raise to 1 by 7. So, one, the, where you use the breaker depth and breaker height, all this information is, either you use it for evaluation of the wave forces due to breaking waves, or maybe, it can be in the coastal engineering practice, to estimate sediment transport, etcetera. So, that is a different subject by itself, but you should know that, there are formulae available; apart from this, there are several other formulae, but I am restricting my discussion, only in this, only to this, some of this three formulae.

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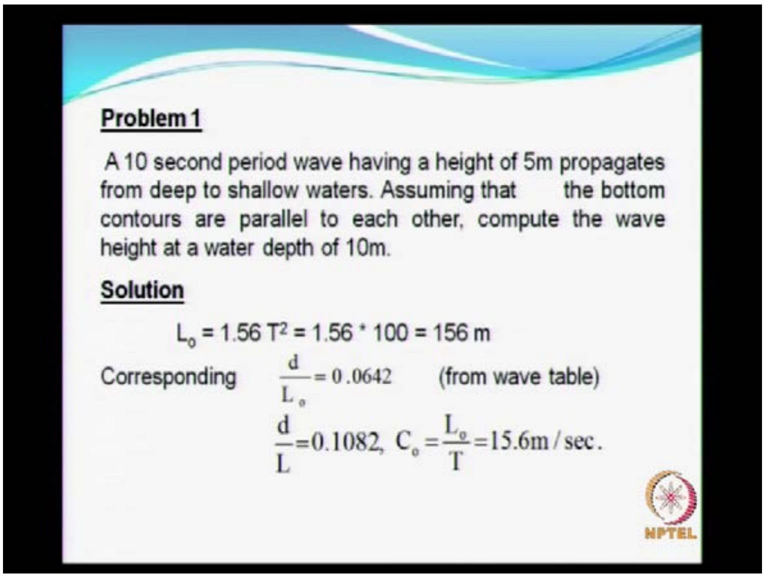

Having seen all these things, now, let us understand some of what we have, what we have gone through, on the topic wave deformation, with a few problems. I will start with the most fundamental problem, and try to show you, the application of the different formulae, and that should give you a broader understanding of the subject, what we are discussing about. Problem number 1, a 10 second wave period, period wave, having a height of about 5 meters here, propagates from deep to shallow waters. The assumption here is, the bottom depths are parallel to each other, something like a ramp. So, this could be the most easiest problem you can think of. So, this is only an assumption. So, there can be loss, or gain; if the bottom sea bed is not even, if it is uneven, you can either have increase in energy, or decrease in energy. So, here, we want to estimate the wave height, in a water depth of 10 meters. So, you already know, how to calculate your wavelength. So, calculate your deep water wavelength; come to d by L naught; then, calculate using, from the tables you can calculate d by L; and then, calculate your wavelength and also the deep water wave celerity, in this case, 15.6 meters per second.

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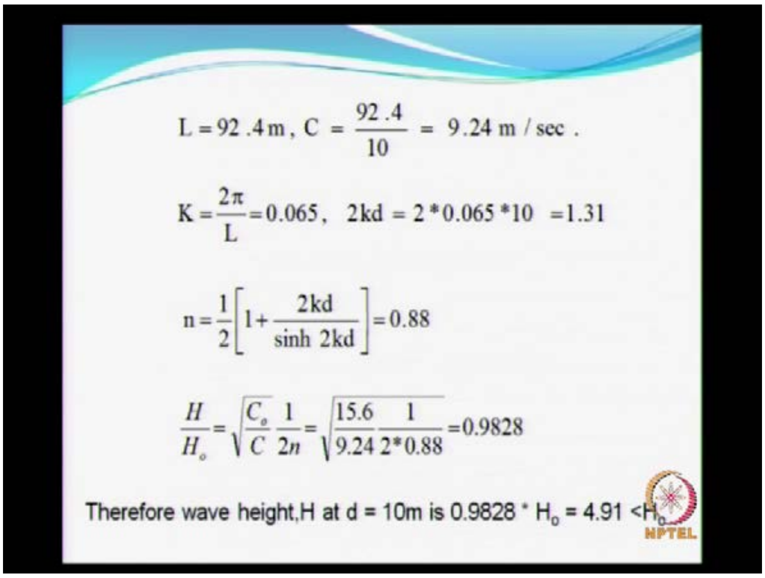

And, celerity from the earlier, earlier value, you can, because the water depth is known, so, you can, from this relationship, you can get the wavelength and the wave celerity is L by t, as we have seen earlier. Now, we have the wavelength, and you can calculate the other parameters, and also the, this is the, all these parameters are needed in order to evaluate the factor n, which can also be taken from the tables directly, from the wave tables. Once this is known, you know what is the relationship; that is, since the bottom depths are parallel to each other, we are now considering the, only the phenomena of shoaling. So, less the, less of a botheration; straight away use this equation, which we have already proved, by equating the power in the deep waters to the power in the shallow waters. So, from this, you get the ratio, the value for the ratio of H and deep water wave height; is that clear? So, here it is 0.98. So, therefore, the wave height in a water depth of 10 meters, is now working out to 4.91. What are the deep water wave height? 5 meters. Now, this is what you get for this kind of a wave period, and this kind of assumption of parallel water depth points.

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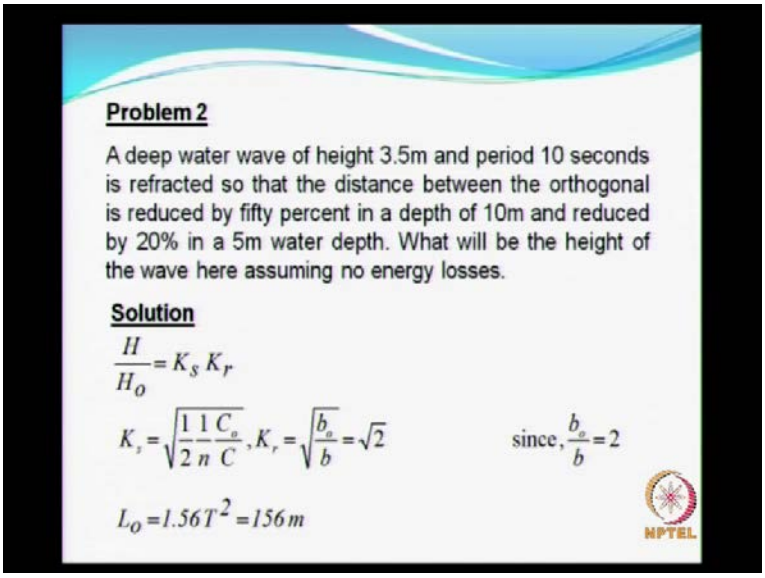

Let us look at this problem, herein the deep water wave height is 3.5 meters, the wave period is 10 seconds and it is refracted, so that, the distance between the orthogonals is reduced by 50 percent in deep, in water depth of 10 meters and reduced by 20 percent in 5 meter water depth.

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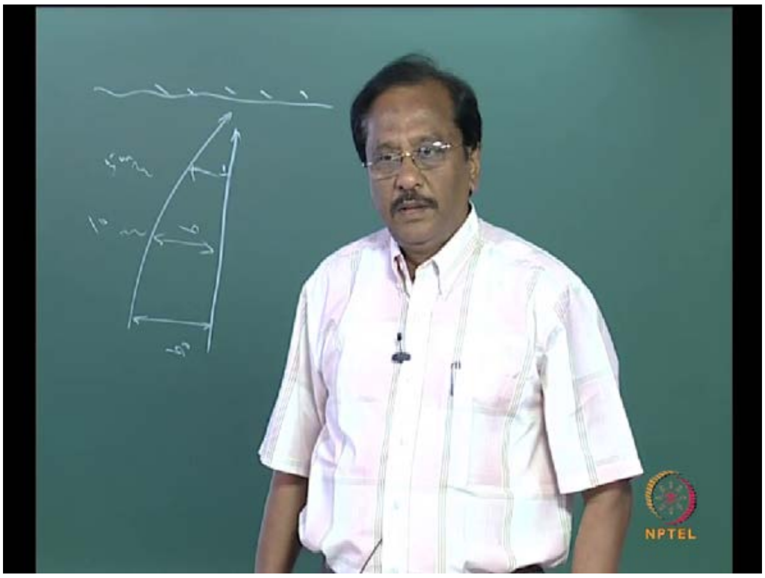

So, what does this mean? This means that, when the wave is, this is the shore. So, when the wave is moving like this, so, you see that, this is the deep water, distance between orthogonals; here, if you have about, something like 10 meters and something 5 meters. So, this is the b; the reduction is said to be 50 percent, something like that; just an assumption. So, here, it is 20 percent reduction; 20 percent means 80 percent of the…This will be 80 percent of the b naught; this will be 50 percent of b naught. b naught is the distance between the orthogonals, in the deep waters. Recollect again, what we have seen under the topic wave refraction. So, as we have seen, we can change the problem also, like, you can have divergence. If you practically do all these things, you will, for a practical problem, if you apply the phenomena of refraction, as we have seen earlier, you can have either the orthogonals converging, or orthogonals diverging. So, here, we have taken the case of convergence of orthogonals. What does that mean? Convergence of orthogonals means, the wave energy should increase; is that clear?

So, based on this, what is the solution for the…So, we, what will be the wave height assuming no energy losses? So, energy loss can be due to so many other factors. We are not considering diffraction here. There can be some amount of energy which is escaping in the lateral direction. So, in this case, what is the solution? What is the expression? H is equal to H by H naught is equal to K s, the product of shoaling coefficient and the refraction coefficient; and the shoaling coefficient you have, already have the expression, as shown here, whereas, refraction coefficient is the ratio of square root of the ratio of the spacing between the orthogonals in deep waters to the spacing between the orthogonals in the shallow waters, any given water depth. Now, as per the problem, it is clearly said, if this is p, b naught, there is a reduction of, by about 50 percent. So, b naught by b is going to be 2. So, your refraction coefficient is square root of 2.

So, when b naught is…Then, you calculate your other parameters, L naught, then, d by L; then, you know how to calculate your K s, as we have seen in the earlier problem; is that clear? Now, you have both your shoaling coefficient and the refraction coefficient; substitute, and get the ratio between H and H naught.

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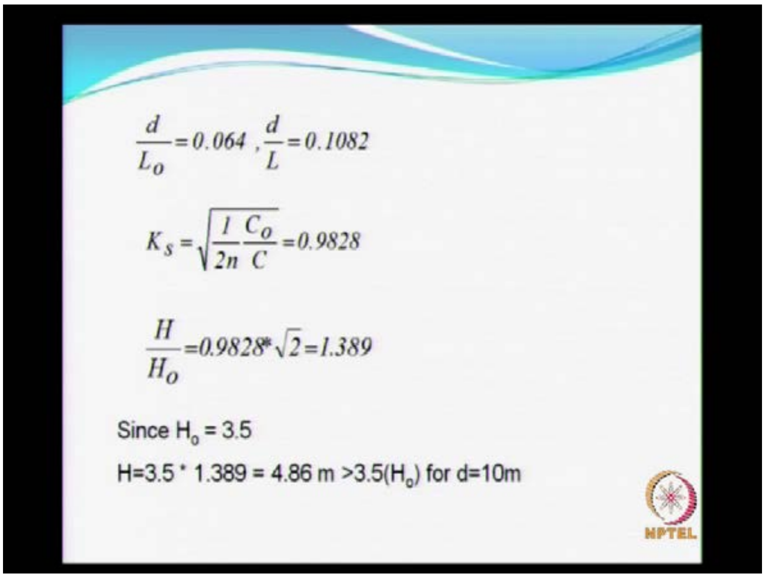

So, you see that, if this is the deep water wave height, if there is a convergence of the orthogonals, the wave height is going to increase; increase compared to H naught; is that clear? What was the deep water wave height? The deep water wave height was given as 3.5 meters. What is the wave height in now, in 10 meters water depth? It is, it is 4.86 meters.

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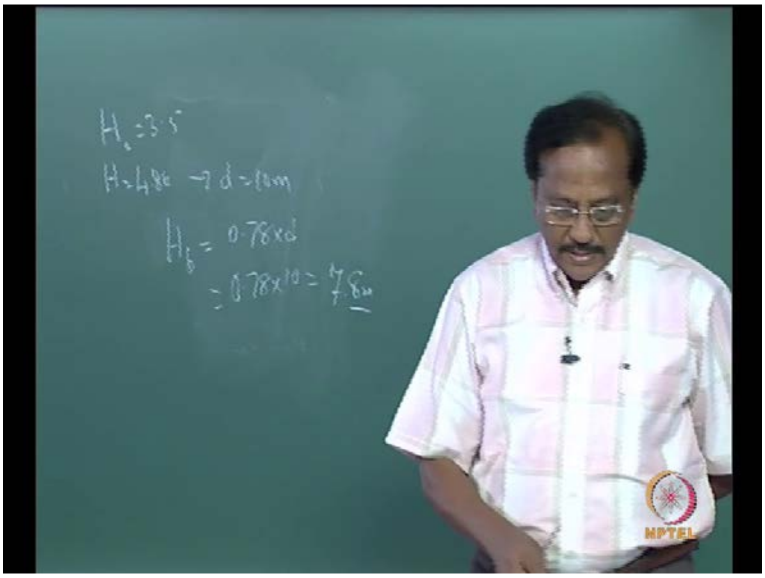

So, you have H naught as, H naught as 3.5 meters. Now, H is equal to 4.86 meters, in a water depth of how much? In a water depth of, in a water depth of 10 meters; is it clear?

The other thing what you have to check is, do we, sometimes you have numbers, but you should also verify, whether that numbers, what you get, is correct or not. So, in this case, because all those values which we have taken for the problem, it is all assumed. I have assumed certain value for the deep water wave height; I have assumed that, the ratio will be, the ratio between b naught and b will be of this value.

So, later, we have to make sure that, the assumptions are correct or not. It should not give some wrong results. There may be a situation that, the orthogonals will never come close. This depends on so many other factors. For example, the ((bathymetric)), etcetera. So, in a water depth of 10 meters, we have a wave height of 4.86 meters. What is the maximum wave height that can occur? That is equal to 0.78 times water depth, which is nothing, but your breaker wave height; breaker wave height is 0.78 times water depth, and here the, this water depth is 10 meters. So, you can definitely have wave height of, upto about 7.8 meters. So, there can be a situation, where the orthogonals can converge, even, less than even what is indicated here. Suppose, by having an assumption, and, if you have a value much greater than this, that means, this kind of a situation will not occur; is that clear?

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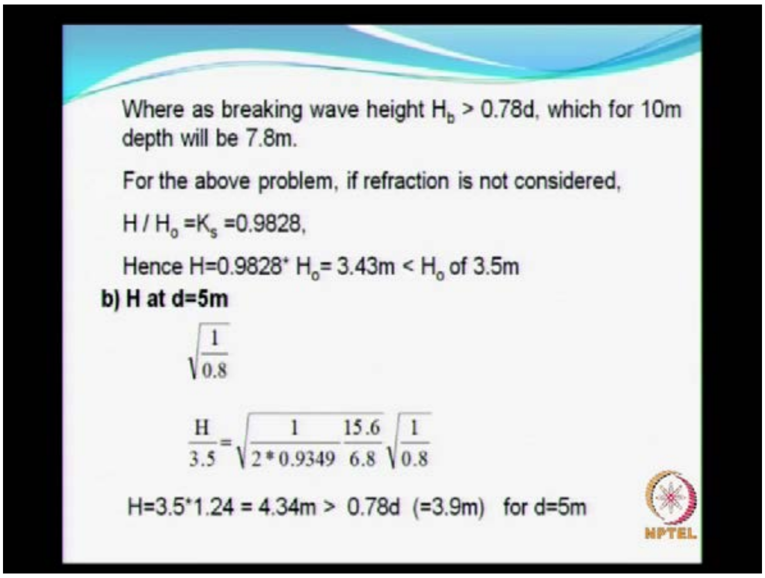

Now, we go into the next…So, this is what is explained here. So, this is what I have explained here, whereas, the breaking wave height of H p, of approximately 0.78 times water depth will be 7.8 meters; this is what I have explained here. For the above problem, suppose, if the refraction is not considered; if the refraction is considered, the wave height is this much; if the refraction is not considered, then, you see that, your shoaling coefficient will be just less than 1, which means, your wave height in 10 meters water depth, will be less than the deep water wave height. Now, is it clear? A wave can increase, or decrease in shallow waters, compared to the, its value in deep waters; it depends on the variation in the bathymetric.

So, earlier, what we did, we did not consider the bathymetric variation. We just considered that, it is a, a slope. Here also, if we do not consider the variation in the bathymetric, you see that, the wave height in 10 meters water depth is less than the deep water wave height. Now, the second, the subdivision, the next subdivision in the same problem is wave height is equal to 5 meters; I mean, in water depth of 5 meters, it is said that, the ratio of b naught to b is 1 by 0.8; it is a 20 percent reduction; is it clear? So, that is what I explained in the beginning of the problem. Now, you calculate that, this is your, sorry, this is, that is your shoaling coefficient; this is your shoaling coefficient and this is your refraction coefficient. Now, you look at the value. The value is something like 4.34 meters. So, will this happen, 4.34 meters? What is, in that particular water depth, in this particular water depth of 5 meters, what would be the wave height? What could be the maximum wave height? 0.78 times water depth, that is equal to only 3.9 meters. But what are you getting here? You are getting a value 4.34, which is greater than 3.9 meters. So, this cannot occur. So, sometimes, it is better to know the negative aspects, so that, you understand the subject more clearly; is that clear?

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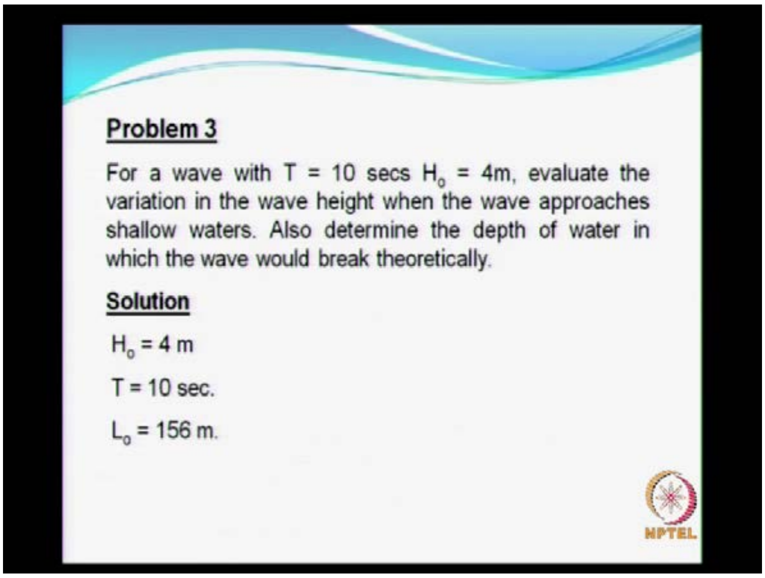

Now, you look at this effect. So, next. So, the previous problem says that, in a situation what we have seen, when you have a reduction by about 50 percent in 10 meters, there may not be a possibility of having further reduction, within 5 meters; that is what it says. So, now, the next problem is for a wave of 10 seconds period, H naught equal to 4 meters. Now, we will try to find out the variation of wave height, when the wave approaches shallow waters from deep waters, and also determine the depth at which the wave would break, theoretically. So, L naught can be calculated.

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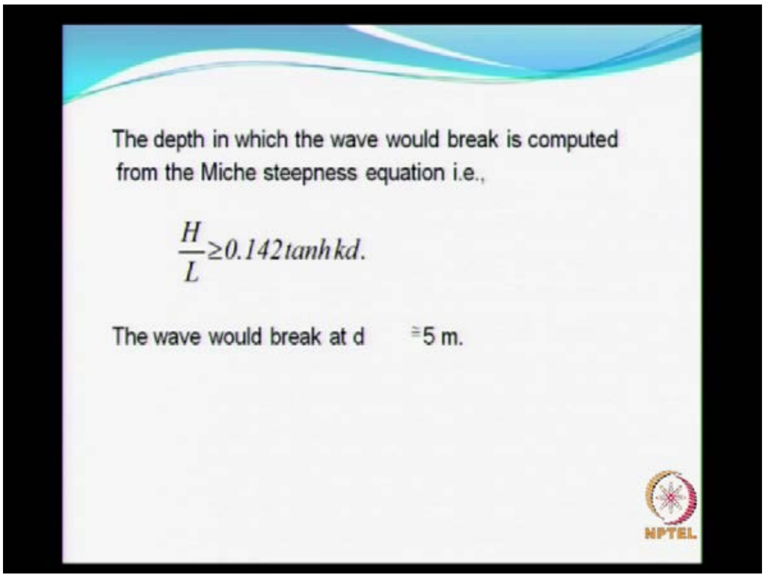

Now, all these things, we are trying to use this definition, which is the Miche's criteria, which we have seen earlier. So, later, you will see, when we examine this, we will see that, the wave would break some, something around 5 meters; but the problem is, in the problem, you have been asked to look at the variation of the wave height.

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Calculation of variation of wave height

d(m)	d/L_o	d/L	L	H/H_o	H	H/L	0.142 tanh kd
70	0.45	0.4531	154.491	0.9847	3.938	0.02549	1390
60	0.385	0.3907	153.57	9728	3.891	02534	1379
50	32	3302	151.423	9553	3.821	02524	.1357
45	.288	.3014	149.303	9449	3.779	02531	.1338
35	.224	.2455	142.566	.9242	3.697	.02593	.1278
25	.160	.1917	130.412	.9130	3.652	.0280	.1169
15	.0964	.1380	108.696	.9358	3.743	03444	.09786
6	.0386	.08175	73.395	1.072	4.228	.05842	.06608
4	.0257	.06613	60.487	1.159	4.636	.07664	.05504

Now, I take a water depth of 70 meters. I start from 70 meters. What is the criteria? The criteria is H by L, H by, H by L is 0.1472 tan h k d; this is the well known criteria. Now, what does this indicate? So, we will use this. Now, try to arrive at the, the relationship on the right hand side and the left hand side, with the help of this problem, where the water depth starts from 70 meters. And, for 70 meters, I have calculated d by L naught; d by L; wave length is calculated; then, H by H naught is calculated, from which I can obtain H; and then, H by L; and then, this parameter, which is on the right hand side. Which are you supposed to, which are the two, which we are supposed to monitor? We are supposed to look at the variation of these two. So, all through, you see that, H by L is less than 0.142 tan h k d. So, this is less than this, all the way; until somewhere here, you see that, between 6 and 4, you see that, this is less than this, but then, this value increases; so, that means, the wave is going to break, in between 4 and 6. So, this is a problem, which explains you the depth limited breaking, the criteria of depth limited breaking; the depth limited, as well as your steepness also.

Suppose, in case, you have only the deep water, then, your tan h k d will not come into picture at all; only H by L will come into picture; since that water depth is also included, I am calling it as depth limited, as well as steepness.

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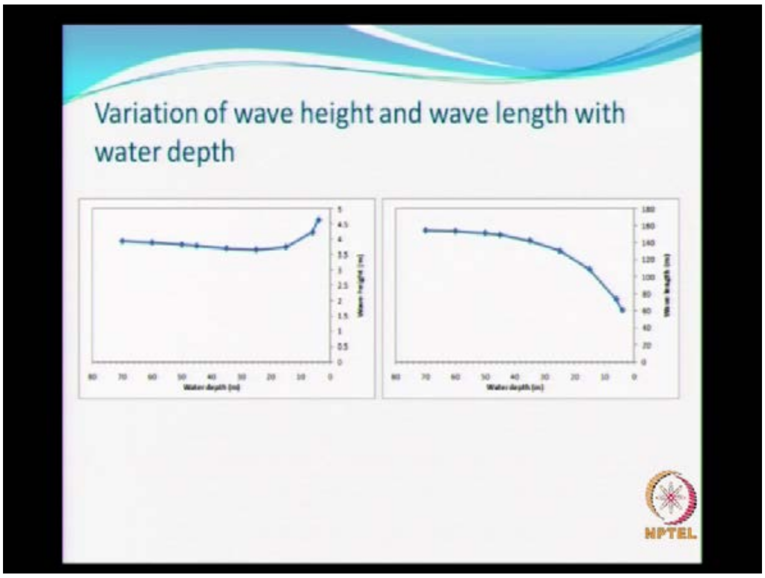

Now, for the same problem, what I have shown here, is the variation of your wave height, from a water depth of 70 meters, and you see that, there is a gradual decrease, and as you proceed towards the coast, you see that, there is a slight increase in the wave height, and somewhere close to the breaking condition, the wave will break. And, this figure, the right hand one, right, right side, the variation of the wavelength is shown, for the above problem; that is, as you go towards the shore, the wavelength is going to decrease. So, these two phenomena, we have examined in this.

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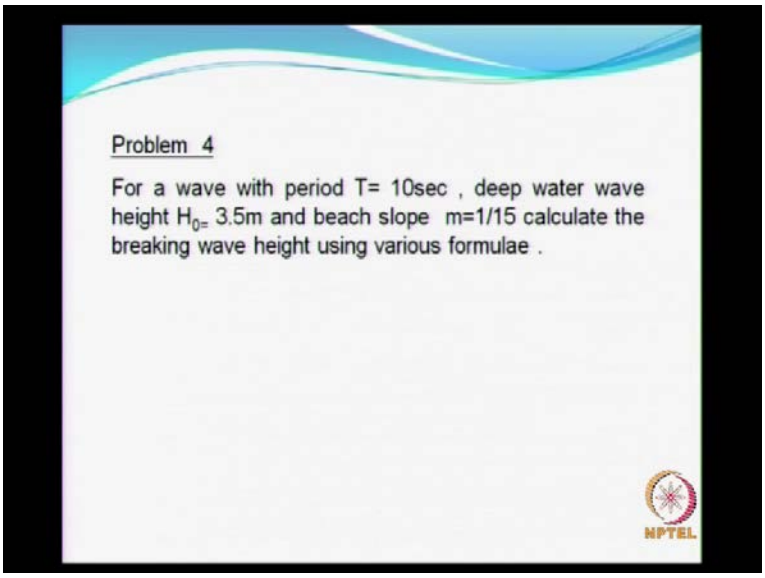

So, we will look at a final problem for today. So, for a wave of about 10 seconds, for a wave period 10 seconds, deep water wave height is given, and beach slope is 1 is to 15. Calculate the breaking wave height, using various formulae. Earlier, we have seen about three formulae. Now, I will list some, few formulae; I will not try to solve, because it is all just application of some simple formulae, but you will get the variation in the wave height predicted by the, some of this formulae.

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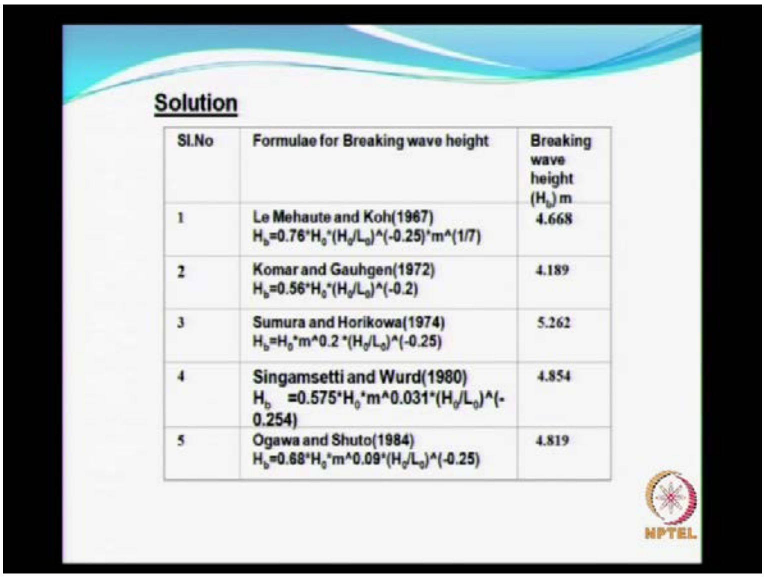

Solution

Sl.No	Formulae for Breaking wave height	Breaking wave height (H_b) m
1	Le Mehaute and Koh(1967) H_b=0.76*H_0*(H_0/L_0)^(-0.25)*m^(1/7)	4.668
2	Komar and Gauhgen(1972) H_b=0.56*H_0*(H_0/L_0)^(-0.2)	4.189
3	Sumura and Horikowa(1974) H_b=H_0*m^0.2 *(H_0/L_0)^(-0.25)	5.262
4	Singamsetti and Wurd(1980) H_b =0.575*H_0*m^0.031*(H_0/L_0)^(-0.254)	4.854
5	Ogawa and Shuto(1984) H_b=0.68*H_0*m^0.09*(H_0/L_0)^(-0.25)	4.819

So, the first one is the Le Mehaute and Koh problem, which accounts for the variation in the beach slope, as, as you can see here, and this predicts the value of 4.7 approximately, for a breaking wave height; whereas, the next, below one, that is Komar and Gauhgen gives a value of about 4.2; and the other one is, the third one is, something like 5.3 and the fourth one is 4.85; and finally, the fifth one Ogawa and Shuto gives you a value of about 4.8. If you see, there are several other formulas as I stated earlier. Mostly the values is around 4.8 to 5, something like that. So, for example, the second one looks slightly underestimating the breaking wave height. So, depending on the kind of wave you have, there are several other kinds of formulas, for the breaking of, estimating the breaking of waves. So, I think we have seen enough on the breaking of waves, and then, in case you have any questions, you can ask me right now. So, if not, I assume that, it is all clear for today. Thanks.